Miscellaneous projects
Folio 1

# H O S P I T A L S

# I N

# A I R  R A I D  S H E L T E R S

# " B U N K E R  H O S P I T A L S "

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Frankfurt am Main

Offenbach am Main

Mannheim am Neckar

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Prepared by:

U. S. Naval Forces, Germany
Technical Section (Medical)

Germany (Territory under Allied Occupation, 1945— U.S. Zone) Office of the Naval Advisor

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# FOREWORD

This brief report on "bunker hospitals" was prepared to give some idea of the various types seen in Germany. A complete hospital entirely underground as a structure so designed and built is not known to us here. Extensive use was made of old salt mines as storage and factory sites and they appear to have served this purpose well. It appears that they could as well have been used as hospitals although no such use is known.

Attention is invited to the report of the Strategic Bombing Survey Commission. It is understood that one section of this survey discusses various types of hospitals and air raid shelters. Considerable local search has not brought a copy of this report to hand so no comment can be made other than to call attention to its existence.

One set of the general plans for the bunker hospitals of Frankfurt and Offenbach have been bound separately, and will be sent to the Planning Division, Bureau of Medicine and Surgery.

Any surplus copies of this report will be sent to the Publications Division, Bureau of Medicine and Surgery.

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# THE SUBTERRANEAN BUNKER HOSPITAL IN FRANKFURT/MAIN

## A. GENERAL SURVEY

### The Project.

The protection of the patients in bombproof bunker hospitals became a major problem when the air raids increased in number and intensity. The simple shifting of the hospitals to less densely populated areas did not present an entirely satisfactory solution. It is out of the question to denude a city such as Frankfurt with 550,000 inhabitants of all facilities for urgent operations and first aid treatment. Special provisions had also to be made to secure first aid on a large scale in case of an air raid.

The bunker hospital under review was originally planned as a one story building, limited to the installations actually contained in the first floor. When the work was in process, the plan was modified in favor of a two story building in order to secure more space for beds. The bunker was definitely not intended as a permanent accomodation for the patients, but as a temporary shelter. The subterranean passages connected it with the basement of the children's and women's clinic next to the elevators, so as to facilitate a smooth evacuation of the patients on their stretchers. The patients who were allowed to be ambulatory were supposed to stay in the corridors of the bunker. No persons other than patients and personnel of the hospital were, as a rule, admitted to the bunker. The Frankfurt bunker hospital was built in 1941 to 1943 and was considered as perfect as scientific and mechanical skill could make it at that time.

The project of a bunker above ground had to be abandoned as this would have interferred with the adjacent buildings, although the cost and protection factors are clearly in favor of a structure above ground. Earth thrust and the influence of ground water constitute additional hazards to the underground construction.

### Time of Construction

The work was started in April 1941. The concrete structure was finished in September 1942. The wards in the first floor were only used in 1943. The rooms had, however, been used as a simple shelter ever since 1942. The bunker was reported to be in full operation in July 1943.

## General constructional Data

The bunker covers an area of 2,261 square meters (that is about 2,710 square yards) and the structure is below the surface. It comprises six operation rooms, flanked by the necessary anterooms etc. Two rooms for sterilization, one room for plaster bandaging and another for the X-ray machinery complete that part of the building. A clear separation of the septic and aseptic treatment is observed throughout. The first floor comprises furthermore a complete bathing facility for men and women, a few small rooms for patients, pantries, toilets, bedrooms for nurses and doctors. The important engine rooms take much of the space of the first floor. Two passages lead to the women's clinic. The height of the ceiling of the first floor is 3 meters (about 9'10"). The first floor has space for 32 beds for patients and 27 beds for the attendant personnel.

The second floor has space for 429 beds, arranged in tiers of two. 62 of these beds are for children which were not arranged in tiers. Passages connect the upper story with the women's clinic and the children's ward of the dermatologic clinic. The respective number of bathing installations, pantries, and toilets is provided for. The room of the Diesel engine goes through to the first floor, furthermore we find a battery and a filter room. The height of the ceiling is 2.30 meters (about 7'8"), 200 seats are provided in the corridors which are 2.70 meters (about 9') wide.

Each of the stories connects with the outside by passages. Special gas proof air locks secure a safe access under all circumstances. A special organization was set up for the case of a necessary treatment of patients injured by chemical weapons. The flight of rooms intended for the neutralization of chemicals is located on the south-east side of the bunker and connects with the outside by a ramp. After being decontaminated and provided with new clothes, the patients, men and women separated, may proceed to septic or aseptic treatment.

## Capacity of the Bunker.

A total number of 488 beds was available. This number included the beds for attendants and doctors. A part of these beds were arranged in tiers of two. The ventilation of the bunker according to the plan was sufficient for 2,000 persons.

## Bomb damages

The bunker was hit only by a few light incendiary bombs which burnt down without any effect on the slabs of the top cover. Several bombs (2oo cwts) fell in the

vicinity (25 yards of the bunker and merely caused very slight damage about 2 inches deep. Apart from a little shaking, no particular effect was noticed in the bunker. The detonation was not heard, the sound waves being intercepted by the many doors and air locks.

## B. TECHNICAL DETAILS

### Architects and Building Contractors.

The general scheme of the bunker was provided by City Counsellor Georg PETRY who was in charge of the planning of all air raid constructions in the City of Frankfurt. Engineer Fritz STROH provided the static calculations. The construction of the bunker was carried out by the firm of KOEGEL of Frankfurt.

### Number of workers, working Conditions.

The work was performed in day and night shifts by about 100 workmen, including about 50 Prisoners of War. Large tents covered the site which made it possible to work with electric light and in cool weather. The tents were heated by stoves and the admixing materials were likewise warmed over, as to permit the pousing of concrete even in winter time. The heating had to be given up temporarily in January, February and early March 1942 because of lack of coal and the work was stopped during this time. This had no special consequences in the further completion of the work. When the air raids in day time increased, the ceiling of the first floor was that far completed that the workers could find shelter at the critical moments. The air-raids did, therefore not considerably delay the construction of this bunker.

### Building Materials.

The main building element was reinforced concrete using B300 grade and ordinary reinforcing steel. Bricks were used for the partition walls which, however, in no case had to take any stress. Small quantities of ceramic tiles and non-ferrous metals were used for the interior.

a) Concrete. The static calculation was based on a compressive strength of 300 kilograms per square meter of solid cube of concrete after 28 days (about 4,260 pounds per square inch) and the permissible load resulted was 75 kilograms per square meter (about 1,065 pounds per square inch). The actual values of compressive strength as set forth in the official report of approbation of the City of Frankfurt were as follows:

| | | | | | | |
|---|---|---|---|---|---|---|
| Floor - first story | 481 kg/cm$^2$ | abt. | 6,830 | pds./sq.inch. | | |
| Ceiling - first story | 391 kg/cm$^2$ | " | 5,552 | " | " | " |
| Ceiling - second story | 462 kg/cm$^2$ | " | 6,560 | " | " | " |
| Bombproof appendages | 420 kg/cm$^2$ | " | 5,964 | " | " | " |

The concrete was introduced by funnel shaped contrivances and then compressed by a vibration jolter. The addition of "Betonplast" in powder form was made to make the concrete more plastic and dense and to increase the impermeability to water.

The maximum daily output of concrete was about 405 cubic yards. The cement used was a normal Portland quality as specified by German DIN Standard Pos. Nr. 1164. Samples were taken at random every day to check on the fineness of grinding, setting time, and constancy of volume. Six samples were taken every day from different charges of ready mixed concrete and sent to the Office for Material Testing of the City of Frankfurt to have the compressive strength checked. The admixed sand and gravel came from the Rhine River. The granulations were checked continually by mesh tests. In the following, the proportions of mixture for different parts of the bunker are given:

Floor of first story

| | | | |
|---|---|---|---|
| 0.215 m$^3$ | (0.281 cb yds) | of sand Ø 0.0 to 3mm | 370 kg |
| 0.093 " | (0.125 " ) | of gravel Ø 3.0 to 7mm | 140 kg |
| 0.300 " | (0.390 " ) | of split Ø 7.0 to 30mm | 470 kg |
| 0.608 m$^3$ | (0.796 " ) | of admixtures | 980 kg |
| | | Portland Cement | 200 kg |
| | | W a t e r | 7,5 % |

Outside Walls

| | | | |
|---|---|---|---|
| 0.160 m$^3$ | (0.210 cb yds) | of sand Ø 0.0 to 3.0mm | 224 kg |
| 0.160 " | (0.210 " ) | of gravel Ø 3.0 to 7.0mm | 253 kg |
| 0.160 " | (0.210 " ) | of split Ø 7.0 to 30 mm | 253 kg |
| 0.160 " | (0.210 " ) | of split Ø 30 to 70 mm | 250 kg |
| 0.640 m$^3$ | (0.840 " ) | of admixtures | 985 kg |
| | | Portland Cement | 200 kg |
| | | Water | 4,7 % |

According to the reports of the City of Frankfurt the following quantities of materials have been used:

25,879 tons of gravel and sand
7,007 tons of split
4,870 tons of cement

The bunker including the connections to the clinics represents the following quantities of concrete:

6,600m$^3$ (8,650 cb.yds) specially reinforced concrete

9,200m$^3$ (12,050 " ) normally reinforced concrete

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15,800m$^3$ (20,700 " ) Total Quantity

b) Reinforcing material. Normal constructional steel with a maximum resistance of 1,200 kg/cm$^2$ (17,000 pounds/sq. inch) was used. The tests had shown that no considerable increase of the resistance values could be obtained by the use of high grade steel or reinforcement by steel strings. The dimensions of the steel, the favorable distribution and a perfect bond are the most important factors. With the view of distributing the reinforcement over a maximum of space, small diameters up to 18 millimeters were chosen. Apart from the statically required reinforcement, a special protective armour against the bombs had to be imbedded into the concrete. The total quantity of steel used for the reinforcement of this bunker amounts to 441 tons, an additional quantity of 280 tons was used for the doors, tubes etc.

c) Method of reinforcement. In the beginning of the construction the so called "cubic reinforcement" was adopted the static forces of which intersect tridimensionally at right angles. Later on preference was given to the "helical reinforcement" which was introduced and locked by cross irons which were put in on a slant. Towards the end of the construction, the so called "Magdeburger reinforcement" was used for certain sections of the ceiling which consists of special cross irons of tridimensional static effect. The bombproof top ceiling was build in small strips to exclude the hazards of the tension due to the contraction and heat disengaged by the setting of cement which may attain at times 65° C. In consideration of its purpose no expansion joints were provided in the concrete. The interior stress bearing 60 centimeters thick were reinforced by a wirenet connected with the transverse reinforcement by special loops.

## Constructional Components

Base of the bunker. The floor of the first story is below ground water level and requires insulation which is achieved by a triple layer of bitumen felt fused to a layer of meagre concrete (6" thick). A thin protective coat of plaster (2") separates this insulation from the foundation properly speaking, namely a reinforced concrete slab, 25" thick and a final layer of meagre concrete, 30" thick. A system of slots for the ventilation tubes is cut into the top layer which connect with the engine rooms. A "floating" floor slab was provided to eliminate the sound oscillations by tread, in that a layer of saw dust, covered by tar paper, was put in between the xylolite floor and the concrete base. The floors of the operation rooms, sterilization rooms and ante rooms were tiled. The engine rooms, toilets, baths, and pantries were likewise tiled. All the other rooms had xylolite floors. The corridors were covered with stone slabs laid in mortar.

Floor of the upper story. The floors of the first floor are constructed in a similar way on a solid reinforced concrete ceiling as base.

The bombproof ceiling has been described above. The concrete slab is about 80" thick. On top of it, we have a layer of concrete (12") prepared of blast-furnace slag for insulation purposes and finally a layer (4") of hard concrete which serves as a base for the concrete slabs which were prepared on the site. To make the slabs weather resistant a special insulation with bitumen and felt was provided.

Outside Walls. The outside walls are 3¼ yards thick and reinforced helically. An insulation was provided for those parts of the outer walls which are in direct contact with the soil. The necessary slots for the tubes for the ventilation and wires etc., were cut into the outside walls.

Partition Walls. The partition walls without stress were made of bricks, 4 and 10 inches thick. Pumice stone concrete slabs and other materials were not used because of their inferior resistance values and sound conductivity.

The passages. The subterranean passages to the clinics connect the elevators in the basement with the air locks of the bunker. The passage from the women's clinic connects with both stories of the bunker. The construction is rather solid as to afford protection against bomb splinters and artillery projectiles. The ceiling is 25" thick, the sides measure 20", the floor 10". The passages are insulated with bitumen on all sides. The different levels make a considerable inclination of the passages necessary (up to 15%) which is a hindrance in the evacuation of the patients on the stretchers.

Details on plumbing and wiring. Special attention was paid to an easy access to the tubes and wiring. Special slots were provided in the walls which had sheet metal covers. More than 10 miles of power current cable were installed. The total length of the telephone and signal wires reached about 8 miles.

Foundation. According to the report of the City of Frankfurt the highest ground water level was +93,30 meters above the normal level. The lower part of the foundation lies at +89,38 meters above the normal level; a drainage was, therefore, necessary. Four diaphragm pumps with individual motors lowered the water level in the area of the bunker by 4,65 meters. The work was performed between sheet pilings. To lower the pressure of the soil, a part of the adjacent soil, a part of the adjacent soil was removed previously. About 200 meters of sheet piles were used and left in the soil upon completion of the work. The connecting passages were built under the protection of steel sheet piles which were removed upon completion.

Static calculation. The static calculation was based on the rules laid down in the official directives concerning the construction of air raid shelters. The calculations are based on a working load of 1 ton per square meter (2,048 pounds/sq. ft). The ceiling was calculated as a continuous system. The necessary strength required to provide protection against bombs was added to the statically required constructional values. The sides were calculated for the soil pressure and bomb protection. The lifting power of the subsoil water was duly taken into consideration. The insulations against subsoil water were described above (See"the base of the bunker,"page 6.)

## C. DESCRIPTION OF THE DIFFERENT ROOMS.

### The first Story.

The first story contains the clinical rooms conveniently centrally located namely 3 aseptic operation rooms with the necessary ante-rooms, an aseptic sterilization room and a separate amphytheater. Separated by partition walls, built of bricks between the 60 centimeters strong pillars of reinforced concrete, we have 3 septic operation rooms with the necessary ante-rooms, a septic sterilization room, and a septic amphytheater. The X-ray and plaster bandaging rooms may be used by both, the septic and aseptic sections and are located so that the patient may be easily brought to one of these rooms while still under narcosis. Ten rooms for patients are grouped around the central flight of rooms for medical use. The patient rooms measure 3,17 by 4,25 meters and have four beds. The rooms of the doctors and attendants are also located here. The necessary hygienic installations such as toilets, lavatories, baths and pantries

complete this part of the building. Patients injured by chemical weapons can be brought into the first story over a ramp. They come first to the reception room and men and women proceed separatedly to the shower rooms and from there, after having been provided with new clothes to the different doctors. The technical installations occupy a great part of the first story. Two passages lead to the women's clinic, besides this, the first story connects with the outside by two staircases with a convenient inclination (17/30 centimeters). All the entrances, passages, ramps, and staircases connect with the air locks. Two inside staircases connect with the upper story.

The operation and preparatory rooms. The size of the operation rooms is 6 by 3.72 meters, the ante-rooms measure 3.65 by 3.71 at a height of 3 meters. Both rooms are tiled 2 meters high. The floor of the operation rooms is likewise tiled and has a slight inclination to the center where a floor drain is fitted. Only part of the ante-room floor next to the wash basins is tiled, the rest is xylolite. Built in closets and the usual sanitary elements characterize these ante-rooms. A wash basin is also fitted in the operation rooms. Two big built in closets in the operation room provide enough space for the instruments and dressing material. The supply of fresh air of the operation room is achieved by a special fixture suspended from the ceiling and which carries at the same time the operation lamp. The waste air of the operation room is removed by a special and separate machinery, to avoid that the ether fumes etc., get mixed up with the ordinary waste air. The operation rooms have additional electric heating and are said to be absolutely free from draughts. The floor drain is equipped with a special flush system which can be operated by a faucet next to the wash basins. Stationary operation tables have not been provided with regard to the limited space, furthermore a certain mobility and versatility of the whole installation has been striven for.

The X-ray Room. The walls of this room, the same as all clinical rooms, are tiled up to 2 meters. The floor, however, is made of xylolite and covered with linoleum. A small control room is attached to the X-ray room which has a window opening on the latter to permit the operator to follow the procedure and take the instructions of the physician. A small sanitary element is lodged in a small adjoining chamber which serves at the same time as a lock to the dark-room. This dark room has all the customary installations and devices. The X-ray room has two entrances, one from the corridor, the other from the operation rooms.

Sterilization-room. Floor and walls are tiled. The sterilization apparatuses are built in. The necessary hot air and steam is supplied from the engine-room. If the engine rooms give out for one reason or another, hot water and hot air can be prepared by

electric devices. In one of the ante-rooms is a container for about 150 liters of distilled water, and another 100 liter container for sodium chloride solution.

Corridors. The corridors are 2.70 meters wide and 3.00 meters high. Many built in closets provide additional space for laundry and drugs etc. Long benches were at the disposal of the patients who were allowed to be ambulatory and who came there when an alert was given.

Rooms for the patients. Four patients are accomodated in one room measuring 3.17 by 4.25 meters. The nozzle for the fresh air supply is suspended to the ceiling over the door. Ordinary beds are used. Each room has a wash basin and small built in closets or foot lockers.

## The Diesel-Room.

The Diesel room is located in a vertical axis in both stories. Apart from the engines the room contains two large fuel containers with a total capacity for 3 days. A double T beam at the ceiling carries a travelling crane. The Diesel engine which was originally intended for this bunker was never installed. A much smaller engine was built in instead which cannot supply the necessary amount of current for the heating, the pumps, lighting, ventilation etc., if the mains give out. A special elastic foundation absorbs the vibrations and the noise of the engine by special vibration absorbers. The double doors are sealed by a rubber gasket and bar the vibration noises. The room has a special ventilation and connects only with the air lock to make sure that no waste gas may escape into the bunker.

## The Engine Room

The engine room contains all the machines which are necessary for the ventilation, heating, drinking water supply and disposal of waste water. Originally there were two shaft pumps for the emergency supply of water. One of these pumps has been removed in the meantime.

The bunker is air conditioned by four elements and a temperature of 20 to 25° C. is maintained. The average requirement of electrical energy of the engine room is 80 kilowatts per hour. The engine room, as are all the technical rooms, is tiled. The floor lies somewhat below the general level. The entrance connects with the air lock. A separate room contains the sewage pumps. Two pumps push the waste water from a central container to the main sewage pipe which lies above the ceiling of the bunker.

## The upper Story

The upper story is in the first place reserved for the patients and has 429 beds. Besides the patient rooms there are the necessary pantries and toilets. Finally there are the Diesel room, a gas filter, and the battery room. Passages connect with women's and children's clinic. Two interior staircases connect with the lower story. The ward for children of the dermatologic clinic is isolated from the rest of the rooms because of the infection hazards. Most of the beds in the upper story are arranged in tiers of two, except for the children's beds. 23 rooms with 10 beds each and about 19m$^2$ surface constitute the main part. The corridors are also 2,70 meters wide and have rows of built in closets. The height of the ceiling of the upper story is 2.30 meters.

Filter room. The complete intake of fresh air can be switched over the gas room in case of a suspicion of gas. 40 carbon filters manufactured according to the directives of the Air Ministry were ready to filter the air. The filter room connects with the air-lock and is tiled. The filters have never been used but were considered as perfect as they could possibly be in 1944.

Battery room. A battery room was provided for emergency cases. According to the original plan there were 60 batteries, later on the number was doubled, since the current was not sufficient to operate the eye-magnet. The capacity of these batteries is sufficient to maintain the emergency lighting of the corridors and operation rooms. They provide 240 Volts, An automatic switching gear turns on the batteries if the mains give out.

Telephone switchboard. When the telephone system of the hospital was badly damaged as a result of an air-raid, a special switch board was provided in the first story of the bunker. The installation of this switch-board for 100 connections did not present any remarkable difficulties and it worked satisfactory. It was removed, however, when the war was over.

Patient rooms. The patient's rooms of the upper story are furnished much the same as the rooms in the first story. The beds were arranged, however, in tiers of two. This arrangement was not much in favor, since it complicates the attention to the patient.

The Pantries. The pantries are mainly intended to facilitate the distribution of the meals which are prepared in the main kitchen. They are equipped with an electric stove and refrigerators. A certain provision of food was stored in the pantries for emergency cases. Large scullery sinks and the customary kitchen utensils complete the interior of these pantries. The floor and the walls are tiled.

Corridors. The corridors have the same width, namely 2.70 meters, as in the first story and are tiled. Special signal lamps can be operated in each room. Large rows of built in closets flank the walls and contain laundry and drugs. Benches provide seats for 200 ambulatory patients. Fire faucets and fire hoses are hung to the walls and are easily accessible in case of fire.

## D. THE SUPPLY MAINS

The average consumption of water of the bunker was stated to be 40m$^3$ per hour. This water is supplied by the City mains. The water is slightly warm when coming to the faucet because all rooms are heated. If the main gives out three shaft pumps can be put in operation, the water so obtained is uncontaminated and could be consumed without having been boiled according to the test result of the City health authority.

### Supply of Current

The current is normally supplied by the City Mains. If it gives out, the bunker generator is automatically put into operation. In addition the batteries may be used in an emergency case.

### Supply of Gas.

The bunker has no gas stoves because of the danger of explosions. It was furthermore considered that the open gas flames use up oxygen. Elextricity is used exclusively for cooking purposes.

### Ventilation

Fresh air is sucked in, filtered, cleaned and heated to room temperature. The intake openings are placed 5.70 meters above the top of the bunker on special towers.

### Heating

For the time being, the bunker is heated by the heating plant of the hospital, an individual heating system of the bunker has been provided and can be put in operation.

### Removal of Waste Water

The waste water of the whole bunker is collected in a container located next to the sewage pump station. The water is then pumped to the sewage pipe of the city sewage system. Since the sewage collector of the bunker lies below the sewage pipe of the city, a special trap and receptacle was put in between the sewage pipe and the bunker system to avoid a back flow.

## E. PROBLEMS OF THE SERVICE OF THE BUNKER

### The Transportation of the Patients.

The patients are carried from the clinics to the bunker through the passages which have an inclination up to 15%. There are no elevators in the bunker. A transport between the stories has to be done over staircases. The lower story of the bunker connects with the outside over a ramp, whereas the upper story has only staircases. The staircases were only used by patients who were allowed to be ambulatory.

### Gas Tightness

The bunker was built in accordance with the directives concerning the construction of air raid shelters issued in 1942. The sheet metal doors of the gas sluices had special rubber gaskets. In addition to this the main doors of the different sections of the bunker were gas tight. A satisfactory gas tightness was achieved.

### The Noise Problem

Special constructional features of the bunker absorbed the vibration of the engines on the spot. The arrangement of doors bars the noise completely. The special construction of the floors was mentioned before.

## F. EXPERIENCES IN THE PRACTICAL USE OF THE BUNKER.

### Opinion of the Doctors.

All the doctors interviewed on the subject found the general layout of the first story highly satisfactory. No proposals for amendments could be made, except that the operation rooms were considered somewhat small.

Objections were raised against the fixture of ventilation being right over the operation table, which causes currents tending to contaminate the instruments very rapidly. It was mentioned that the sterility of the instruments lasted only for about half an hour. Special attention must be paid to the proper dimension of the waste water pipe and the floor drain. Special traps should not be forgotten. The ventilation is suspended in square shaped ducts to the ceiling. The doctors objected to this arrangement which causes deposits of dust. It is therefore recommended to put all kind of ducts and tubes in the wall. The accessability of the tubes, etc., can easily be maintained by a proper construction. The doctors furthermore object to the suspension of the ventilation outlets, above the doors of the patient rooms. The draught caused thereby proved to be hazardous for new operated patients. It is proposed to provide several indirect covered outlets to avoid draught and unnecessary stirring up of dust. The absence of daylight makes the bunker unfit for a permanent stay of the patients.

Opinion of the attendants.

The absence of daylight proves unfavorable with regard to the efficiency of the personnel, furthermore the relatively high room temperature has a similar effect. The patients rooms are considered too small and do not allow placing closets for the belongings of the patients. The inclination of the ramps (15%) is too great, it should be 1:10 to 1;12. The narrowness of the rooms makes it difficult to observe strict asepsis. The bunker was used during the air-raids by about 3 to 4,000 people, that is to say about twice as much as it was planned for, the ventilation then proved unsatisfactory. The corridors were often overcrowded and hampered the work of the attendants.

Opinion of the patients

The patients complained about the absence of daylight and the loss of the sense of time.

Illustration 1

A general view from an upper floor of the adjacent children's hospital. The women's hospital on the left, The towers, left foreground and on the opposite side, are the air intakes for the ventilation system. Center background shows damaged end of wing of women's hospital.

Ill. 2

Illustration 2

A diet kitchen in the hospital. Note ventilation exhaust fans on wall. Patients and doctors complained that odors accumulated in the bunker in spite of the ventilation system.

Ill. 3

Illustration 3

Patients room showing bed arrangement. Nurses point out that these were inadquate arrangements for stowing patient's belongings and bedside tables obstructed the passage. During the war there were double tiers of beds in these rooms.

Illustration 4

Service room. Utilities were in every way comparable to customary installations. Note the use of glazed tile on these walls and in other rooms as well.

Ill. 4

Illustration 5

X-ray room. Complete in all essential details. In daily use at present, without change.

Illustration 6

Operating room. Complete in all essential details. Incoming air came into room above operating lamp. Doctors scrub room lies just beyond.

Ill. 7

Illustration 7

Operating room in use. Note use of cotton gloves. Minor surgical procedure in progress. Note cross connection to adjacent operating room on left side. Instrument cabinets are built into the walls.

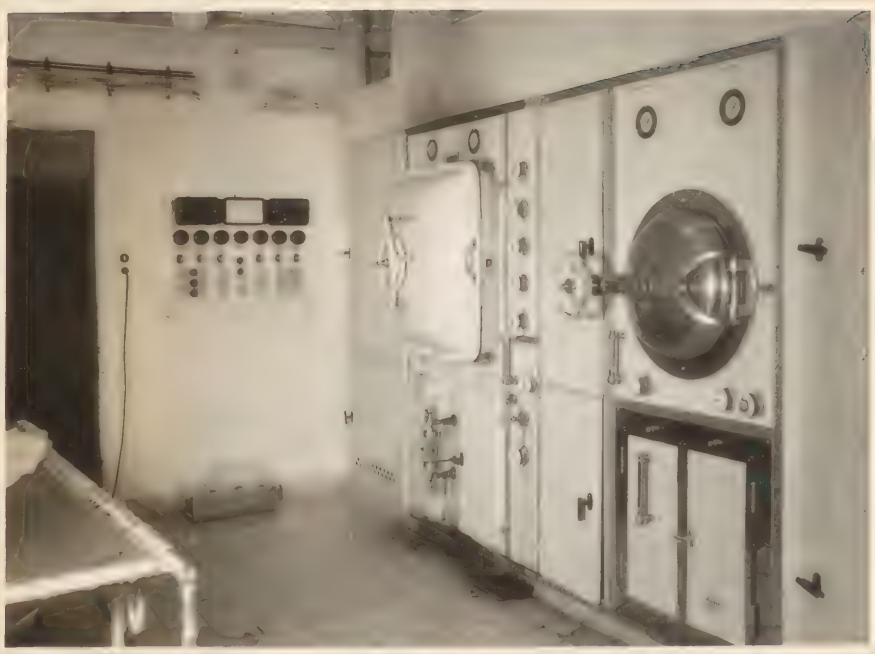
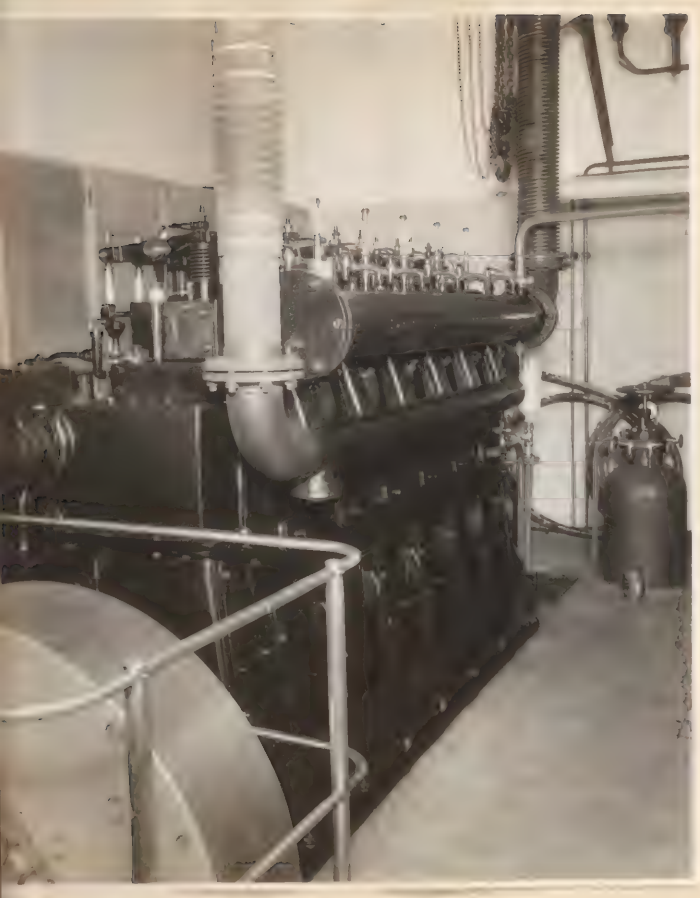


Illustration 8

Sterilization room. Built in equipment with heat removed through exhaust ventilation.



Ill. 9

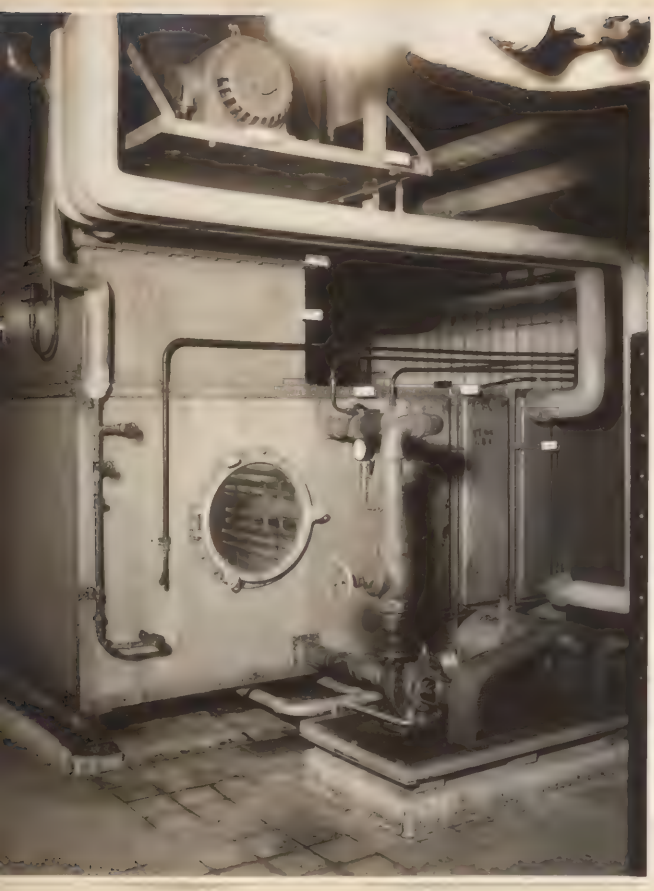
Illustration 9

Diesel motor for generating electric power which furnished lights and operated pumps and ventilating system.

Illustration 10

General view of machinery room.

Ill. 10



Ill. 11

Illustration 11

Part of the climate control equipment. Heating and ventilation systems were combined.

Ill. 12

Illustration 12

Filters for use in case of chemical warfare.

Illustration 13

Auxiliary batteries for use in an emergency, if electric power failed and to hold the load until the diesel powered generator could take over.

# THE HOSPITAL BUNKER AT OFFENBACH ON THE MAIN

## A. GENERAL SURVEY

### The Project

The construction of air-raid shelters for the City of Offenbach was under the supervision of the Commissioner for air raid defense measures of Frankfurt/Main. This explains the fact that the construction of a bunker hospital for Offenbach was planned as early as December 1940, when the same problem arose in Frankfurt. The main object of these bunker hospitals was to protect the patients who had been recently operated upon rather than to serve as a hospital in the true sense of the word. As soon as the patients were at the stage where they could be moved they were evacuated to less endangered areas. The bunker was constructed in such a way as to permit direct access to any of the three floors from the outside. The first floor is completely below ground, while half of the second floor and the third floor are above ground. For architectural reasons the bunker was covered with a false roof, due to this construction and the ample use of worked stone and plaster, the bunker adapts itself satisfactorily to the surrounding buildings as regards artistic similitude.

### Time of Construction

The construction of the bunker was started early in December of 1940. The concrete work began in February 1941 and was finished in the autumn of the same year. The interior work was finished early in 1942 and the bunker was put into full operation immediately after it had already served as a provisional shelter ever since the concrete shell had been completed in 1941.

### General Description of the Bunker

The bunker is located in line with the nurse's home and the main building of the hospital and is surrounded by pathways on three sides. The rooms of the bunker are grouped around a central corridor. The first story provides the patient rooms and has space for 108 beds which are arranged in tiers of three. Besides the patient rooms, the first story has the necessary sanitary installations, baths, and a pantry, and as far as the technical installations are concerned it contains the

room for the Diesel engine and the heating installation. The first story connects directly with the outside by a staircase. Another staircase of four steps connects it with the main building. The entrances are laid out in a manner to afford a maximum protection against bombsplinters; several sharp turns of the entrance passages serve this purpose. The first story provides 54 beds arranged in tiers of two and the necessary sanitary installations. The second story contains the store rooms of the bunker, that is to say the oil, and drinking water containers. It connects with the outside and the main building by conveniently located staircases. The second story provides the medical rooms, namely a septic and an aseptic operation room and between these two rooms a sterilization room and an anteroom with wash sinks for the doctors and a room for anaesthesia.is found. In the second story the beds are not arranged in tiers because this story is reserved for patients who are attended twice daily. The number of beds is 12, two to a room. An X-ray room, a darkroom and a control room complete the clinical part. The necessary sanitary facilities are conveniently arranged. The upper story contains the ventilation machinery and the gas filter in accordance with the directives issued by the German Air Raid Protection League.

## The Capacity of the Bunker

The bunker was built for 174 beds, including those of the attending personnel. The bunker provides furthermore about 100 seats (benches) so that the total capacity is about 300 persons. When counting the people in the bunker during a heavy air raid it was found to contain about 1,500 persons, partly patients of the hospital and partly people from nearby houses. The ventilation was laid out for 350 to 400 persons.

## Bomb Damage.

The bunker was not hit directly by bombs. Several light bombs fell at a distance of about 700 to 1000 meters and caused no damage whatsoever.

# B. TECHNICAL DETAILS

## Work Force. Time of Construction

The work on the bunker was performed in three shifts. The number of workmen employed in each shift varied between 50 and 100 men according to the type of work in process. Large tents covered the site, this made it possible to use electric lamps and to work when the weather was rather cool. Interruptions due to cold did not occur. A powerful portable steam engine was in

operation under the tent to feed the heating coils which served to warm the sand and gravel. The water used for the concrete was likewise heated. With these provisions it became superfluous to add special chemicals and normal cement could be used throughout. As already mentioned under A the excavation work was started in December 1940. In February 1941 after the intense cold wave the concrete work began and was efficiently carried through without interruption and finished in autumn 1941. Supply difficulties of the medical installations explain the fact that the bunker could only be put into full operation in February 1942. The air-raids caused hardly any interruption of the construction, since the attacks at that time were generally flown at night. Unusual event during the construction have not been reported.

## Construction Material

The main building material was reinforced concrete. The static calculation was based on the compressive strength of 300 kg/cm$^2$ of a 20 centimeter cube of concrete after 28 days and the usual values of construction steel.

## Concrete

The exact data concerning the composition of the concrete and the conpressive strengths could not be ascertained since all the documents have been destroyed by fire. According to the information obtained from the architect a rich plastic concrete with an addition of 300 kg/m$^3$ was used. The average compressive strength was about 400 kg/cm$^2$. The grades of the sand and gravel used were as follows:

0.0 to 7.0 mm Ø = 50%

7.0 to 15.0 mm Ø = 20%

15.0 to 30.0 mm Ø = 30%

Washed sharp sand and gravel from the Rhine River and ordinary split were used as admixing ingredients. The cement used was the normal Portland quality.

## Steel

Small diameters up to 16 mm Ø of ordinary construction steel were used. In certain cases the concrete was reinforced with a steel sire net.

## Reinforcement

The reinforcement of the bomb proof ceiling and outside walls was achieved by a helical arrangement of the steel. The distance between each winding is about 20 centi-

meters and the bond was achieved by loops. The concrete was poured in a plastic condition through a funnel shaped contrivance and then compressed by mechanical vibrators. The tests in accordance with the prescriptions of the German standards as to the compressive strength, fineness of grinding, and constancy of volume were carried through regularly. Samples were taken of each batch of concrete at the site and forwarded to the State Office for Material Testing.

## Rammed Concrete

The floor of the first story is made of rammed concrete which was composed according to the statements of the architect as follows:

0.0 to 7.0mm Ø = 20%

7.0 to 15.0mm Ø = 20%

15.0 to 30.0mm Ø = 30%

30.0 to 70.0mm Ø = 30%

Quantity of cement added = 300 kg/m$^3$ of concrete.

The concrete was poured in an earth humid condition in layers of about 20 centimeters and then rammed.

## Foundation

The bunker is located on a grown (natural deposit) formation of clay except for a layer of about 2 meters thick which consists of deposited (river floods) clay. These favorable conditions made it possible to work without any drainage in the open trench. The daily collection of storm water was pumped by diaphragm pumps into the city sewer. To protect the sloped trench against a shifting of the deposited clay layers a supporting breast wall of rammed concrete 4.70 meters high and with a thickness of 30 centimeters on top. These walls were left in the ground upon completion of the bunker and appear in the cross section next to the floor of the first story. The insulation against ground water was achieved as follows: A triple layer of bitumen felt was fused to a 15 centimeters layer of meager concrete. The bitumen felt was then covered with a thin layer (5 centimeters) of cement mortar on which the rammed concrete slap of the floor reposes.

## Management of the Construction

The project of the bunker was supervised by Architect Carl MUELLER, Offenbach/Main. The static calculations were provided by Dipl. Ing. RICKHOFF at Darmstadt. The concrete work was completed by the two firms of MAHR and HUMMEL, Darmstadt. A number of various other firms were engaged in the final stage of the construction of this bunker.

## Constructional Components

The floor of the first story consists of a 1.40 meter thick layer of rammed concrete which is reinforced in the lower zone by a steel wire not because a complete reinforcement was considered too expensive and deemed unadvisable due to the scarcity of construction steel. Special expansion joints had to be provided to take up the considerable amount of tension due to setting heat and shrinkage. These joints are disposed as a slant ( 70 to 80° ) and are filled by fibre plates. The floor slab protrudes into the lateral walls and a kind of rigid fixing is obtained by special loops imbedded into the concrete. The rammed concrete floor is covered with a layer ground cork cemented by a magnesite lye and which provides sound and heat insulation. On top of this cork insulation lies the final floor material which is different according to the purpose of the rooms.

Ceilings. Reinforced concrete ceilings separate the stories. These ceilings are calculated as slabs with three areas of loading and are provided with the usual reinforcement. The lower side is covered with mortar and the upper side with a cork layer and the appropriate floor cover. In the middle corridors a blind ceiling of pumice stone plates was suspended to the ceiling leaving a hollow space of about 30 centimeters which serves as a fresh air duct.

Bomb proof ceiling of the upper floor. The top ceiling, 1.40 meter thick, is reinforced helically and was considered as bombproof in 1941. The spirals of the reinforcement are rather close together at distances of 20 centimeters. A wirenet is imbedded 3 centimeters from the lower surface in order to prevent pieces of concrete from falling down in case the bunker should be seriously hit. The same purpose serves a special protective ceiling suspended to the main ceiling and which reposes on double T beams imbedded into the concrete at a distance of 90 centimeters. Between the flanges of these beams, slabs of pumice stone concrete, 8 centimeters thick, are inserted. The distance between the two ceilings is 30 centimeters. The blind ceiling is covered by a wire net to hold the plaster of the ceiling. The bombproof ceiling supports a lumber roof truss. As mentioned before a roof was provided for architectural and camouflage reasons. In later bunker constructions the roof truss was made of steel because of the fire hazard.

Outside walls. That part of the outside wall which is in direct contact with the ground and which must afford protection against earth thrust and possible action of ground water is made of helically reinforced concrete, 1.80 meter thick. The diameter of the wall of the second story is 1.10 meter plus a 20 centimeters shell of worked stone above level. The wall of the second story at the part below ground is 1.55 meter thick. The walls of the upper story measure 1.14 meter and are likewise made of helically reinforced concrete. Special provision was made to facilitate the extension of the bunker by insert-

ing hexagonal honeycomb shaped concrete slabs into the face walls of the second and third story which are separated from the adjacent structure by a layer of tar paper. These slabs can be removed when the necessity arises without disturbing the bond of the structure. The slab is dove tailed with the walls and in perfect bond. The walls below ground have been insulated to impede water penetration by several coats of bitumen.

Partition walls. All partition walls of the first story are made of reinforced concrete. The walls which have to take stress, that is to say the walls of the corridor are 60 centimeters thick. The partition walls of the rooms measure 40 centimeters. The walls of the corridor have the same dimension in the second and third story. The partition walls of the rooms, however, are made of bricks and are 38 centimeters thick. Several partition walls in the second and third story are made of stucco slabs 5 centimeters thick.

Passage. The passage connecting the bunker with the main clinic is built bombproof and contains the staircases, corridors and air locks. The entrances are staggered and are provided with several sharp turns. In the whole construction the rule was observed that a perpendicular line between any points of the structure must hit on bombproof material. A space was left between the old building and the bunker. The intervening space is closed with bricks on the edges. A few openings protected by meshes serve as intake holes for fresh air.

Tubing and Wiring. The tubes and wires are laid in special slots cut into the walls or covered with plaster to avoid possible deposits of dust.

## D. DESCRIPTION OF THE ROOMS

### First Story

The floor of the first story is about 3.70 meters below the level of the ground. The height of the ceiling is 2.65 meters. The height of the ceiling is reduced to 2.25 meters in the corridor by the ventilation ducts suspended to the ceiling. The first story connects with the outside and with the hospital by staircases protected by air locks. Another staircase leads from the passage of the first floor to the outside. All the walls are made of reinforced concrete. The first story contains the following rooms: 5 rooms with 12 beds each, 2 rooms with 24 beds each, all beds arranged in tiers of three. Furthermore: Lavatories and toilets for men and women, a bath, lavatory for nurses, skullery, a day-room for nurses, a pantry, and an interior staircase connecting with the second story. Two technical rooms are separated by a sound-lock from the clinical rooms, These

rooms are: The Diesel room with the generator and control room and the heating room with hot water boiler and the inlet of the hot air duct, and chimney connection. A rain water collector was built in lat r on when the drinking water proved to be too hard for the cooling of the Diesel engine.

Patient Rooms. The size of the rooms with 12 beds is 2.85 by 4.95 meters, that of the rooms with 24 beds 6.10 by 4.95 meters. The walls are covered with plaster and painted with oil paint. The floor is covered with xylolite. The ventilation is installed over the middle of the door and the waste air outlet is on the outer wall.

Laundry Room. The ante room of the laundry room is provided with six large scullery sinks. The floor and the walls are tiled. In a detached part of this room is a special sink for heavy sewage. A waste shaft for used bandaging materials ends about 1,20 meters above the floor of this room. A portable receptacle is hooked on to the outlet of the shaft. A built in closet contains the laundry. The room is tiled and can be cleaned easily.

Toilets. The toilets for men and women have anterooms with a sink and a washbasin. The anterooms are necessary to avoid an odor nuisance.

Baths. In addition to hand basins we find a large bath tub of ceramic material and a toilet. The floor and the walls are tiled.

Pantry. The pantry is conveniently located centrally next to the nurse's dayroom. The size of the room is 2.85 by 4.95 meters, walls and floor are tiled. The pantry is provided with a large scullery sink and an electric water heater. Two electric stoves are available. The outside wall has built in closets containing dishes and provisions.

Heating Room. The heating room is 5.75 by 4.95 meters and contains in addition to the heating installation the groundwater pump. The floor is covered with cement, the walls are plastered and painted in a light color. The central heating plant of the hospital supplies hot water to this heating room, where hot air is produced in a counter current device and then forced into the radiators of the bunker. Working pressure 8 atmospheres. A chimney 40 by 40 centimeters is attached to the bunker to lead the waste air of the Diesel engine to the outside. This chimney is made of reinforced concrete and is insulated at the inside against dissipation of heat by fibre plates. The ground water pump is actuated by a floater as soon as the ground water attains a fixed level. The water is forced into the city sewage main.

Diesel Room. The Diesel room measures 5.63 by 4.95 meters. The floor is tiled. The walls are painted with calcimine. The Diesel engine reposes on a spring bed plate to absorb the vibrations. The capacity of the engine is 80 kilowatt/Ampère at 1,000 revolutions and has a consump-

tion of 10 liters of oil per hour. This capacity is fully sufficient for all requirements of the bunker. A 100 liter oil barrel is suspended to the ceiling which can be filled by hand pump from the main container in the store room. An open space in the ceiling provides a direct connection with the water storage room. This open space was necessary for the erection of the engine. A special rain water container was built in later on when the water from the city watermains proved to be too hard.

## Second Story

The second story provides 9 patient rooms with 6 beds in tiers of two, a doctors room with two beds, a nurse's dayroom, two lavaratories, toilets, baths and a pantry. The technical rooms of the first story include the oil storage room, and a drinking water storage room. The first story has conveninet access from the outside by staircases, it connects also with the hospital building by a passage. The interior staircase provides the connection with the two other stories of the bunker. The general disposition of the stair cases is the same as in the first story.

Patient Rooms. The size of the patient rooms of the first story is 5.20 by 2.85 meters. The lateral walls are built with bricks. The capacity of the rooms is 6 beds in tiers of two. The equipment of the patient rooms is the same as in the first story.

Toilets, Baths and Lavatories. Same disposition and installation as in the first story.

Pantry. Same disposition and installation as in the first story.

Corridor. The corridor is 2.50 meters wide, the floor is covered with xylolite. The hollow space of 30 centimeters between the concrete ceiling and a false ceiling suspended to it has several outlets and provides the supply of fresh air. Builtin closets flank the walls.

Oil Storage Room. Size 2.85 by 5.20 meters. The floor is covered with cement. The plastered walls are painted with calcimine. A pipe connects with the oil barrel of the engine room. The room has space for about 500 liters of Diesel oil. The room has a gas tight steel door.

Water Storage Room. Five large tanks containing 1,500 liters each contain the emergency water reserve of the bunker. The faucets of the bunker are permanently fed from these containers, so that the water will always be fresh. A small electric pump connects with a tube which leads to the outside of the bunker. Here, the water brought to the bunker in tank wagons can be sucked into the storage tanks. The walls and floor of the waterroom are tiled.

## The upper story

The upper story contains six patient rooms with 2 beds, the necessary number of sanitary rooms and a pantry. The following clinical rooms are included: a septic and an aseptic operation room, a sterilization room, a lavaratory for the doctors, a room for anaesthesia, an X-ray room with dark room, a storage room for drugs and dressing material, an ante-room to the operation room. As far as the technical outfit is concerned, this story contains the ventilation machinery and the gas filters.

Patient Rooms. The arrangement of two beds in tiers of two in each room facilitates the attention to the newly operated patients. The rooms measuring 2,85 by 5.20 meters are furnished with a small closet, a table and two chairs. The walls are painted in washable oil paint. The floors are covered with xylolite.

Toilets and Baths. Same disposition as in the first floor.

Ante Room to Operation Room. This room serves as a vestiary for the doctors. We can find washbasins, a sink for heavy sewage, and a built in closet for laundry. At the wall next to the operation room are hung two geysirs which communicate with the operation room. The floor and the walls are covered with tiles.

Septic Operation Room. The floor and the walls are tiled. Four washbasins and a large scullery sink are fixed to the wall. The intake openings of the waste air ducts are located 9 centimeter above the floor. The inlet nozzles of the fresh air system are located over the entrance door which is 1,50 meter wide. The separation wall to the sterilization wall is provided with a sliding window. The inlet nozzles of the ventilations are provided with special bacteria filters. An additional heating by electric radiators is possible. The size of the operation room is 6.25 by 5.08 meters.

Aseptic Operation Room. The size of the aseptic operation rooms is 6.15 by 5.08 meters thus only slightly smaller than the septic operation room. The floor and the walls are tiled. The wall to the sterilization room is likewise provided with a window. At the opposite wall we can find a large scullery sink and a hand wash basin. A door, 1,50 meters wide, permits to move the patients through the ante room into the anaesthesia room. The ventilation of this room is likewise protected by bacteria filters. The rest of the equipment of this room is the same as in the septic operation room.

Preparatory and Anaesthesia Room. The floor and the walls of the room are tiled. Two washbasins are fixed to the wall. The size of the room is 3.00 by 5.08 meters.

Storage Room. The walls of the storage room are flanked with builtin closets which provide space for dressing material and drugs. The walls are painted with oil paint. The floor is covered with xylolite.

Ante-Room of Operation Rooms. This room was probably intended as a plaster bandaging room. The room is tiled and provided with hand wash basins and a row of built in closets. The size of the room is 5.20 by 2.85 meters.

X-ray Room. The size of the X-ray room is 5.20 by 2.85 meters. Attached to it is a control room and a dark room. The X-ray room and the control room have xylolite floors, the dark room is tiled. The walls are painted.

Room for the Ventilation Machinery. The floor of this room is covered with xylolite, the walls are plastered and painted with calcimine. An electric pump sucks the fresh air in, which is then cleaned, heated humidified and then forced into the rooms by way of the ducts. Four gas filters can be put in operation if gas is suspected.

## E. SUPPLY MAINS.

### Water Supply.

The bunker is connected with the city mains. Due to the fact that it was not possible to drive a pump shaft through the clay foundation, large supply tanks had to be installed for emergency use. For further details see under Storage Rooms.

### Gas Supply.

Gas stoves or heaters are not used because of the explosion hazard and the consumption of oxygen.

### Electricity

The bunker is connected with the city mains. In an emergency case the generator is operated which supplies the ventilation system, water system, lighting and power. The time until the generator attained its full capacity was bridged over by batteries.

### Ventilation

Fresh air is sucked in by an electric pump. The intake openings are located where the bunker abuts upon the hospital building. The construction details have been described above. The operation rooms have a separate ventilation to prevent the ether fumes from interfering with the general ventilation system.

## Waste Water Disposal

The City of Offenbach has no sewage system but only waste water mains. Each house has therefore a special intercepting pits. After the heavy sewage substances have settled the water is conveyed to the mains. The sewage disposal of the bunker works in a similar way. The total amount of sewage is conveyed to a nearby located intercepting pits, where the heavy sewage substances settle down. The water is then conveyed to a two stage clarifier, the first stage comprises first the cleaning of water from suspended substances and then the decontamination. From there the water is conveyed to the sewer.

# F. PRACTICAL EXPERIENCES

## Transport of the patients

The patients can be moved from the upper and lower story of the hospital to the bunker without leaving their beds. In the main hospital building the transport is facilitated by elevators. From the outside the bunker is accessible only over the staircases.

## Gas tightness

The gas tightness of the bunker has not been checked. An overpressure was, however, ascertained by measurements in the interior of the bunker. The outlet valves of the rooms are all provided with back pressure valves so that no infected air can penetrate into the bunker. All entrances are protected by air locks which are closed by steel doors with special rubber gaskets.

## Sound Insulation

Vibrations and sound waves caused by the machinery of the bunker are absorbed on the spot by special spring bed plates. The construction of the floors with special cork layers is highly shock and sound absorbent. The partition walls made of bricks at least 25 centimeters thick, bar the noise almost completely. The doors are made of plywood 2.5 centimeters thick and are sound proof.

## Opinion of the Doctors

The doctors consider this bunker as a complete construction which answers all the medial requirements. The only suggestion that could be made is the installation of elevators.

## Opinion of the attendant personnel

The nurses objected to the arrangement of the beds in tiers of three which presents considerable difficulties in the attention to the patients. The sterilization room is considered too small. It was reported that the ventilation of the upper and lower story were perfect, whereas it was not quite satisfactory in the second, that is to say in the middle story. The personnel complained of the absence of daylight.

## Alterations of the Bunker

By order of military Government windows were blasted into the outer walls of the patient rooms of the upper and lower stories. Besides that no alterations have been carried through and no alterations are planned.

Ill. 1

Illustration 1

General view showing false roof line. The boy is on the railing around one of the stairways connecting the second floor of the bunker with the ground level. The brick faced windows have been blasted in the original structure since the war ended. In the right background can be seen the old hospital. This structure is used to full capacity at present time.

Illustration 2

View from street side showing connection with the old hospital. The four brick faced window openings have been blasted in the wall only recently.

Ill. 2

Illustration 3

View of side on courtyard. One can obtain a better idea of its appearance before the window openings were made.

Ill. 3

Illustration 4

X-ray Room.

Ill. 4

Ill. 5

Illustration 5

Passageway. Note folding seats along the wall intended for ambulatory patients from the old hospital next door or for those from outside who had come for treatment.

Illustration 6

Emergency water storage tanks with pump.

Ill. 6

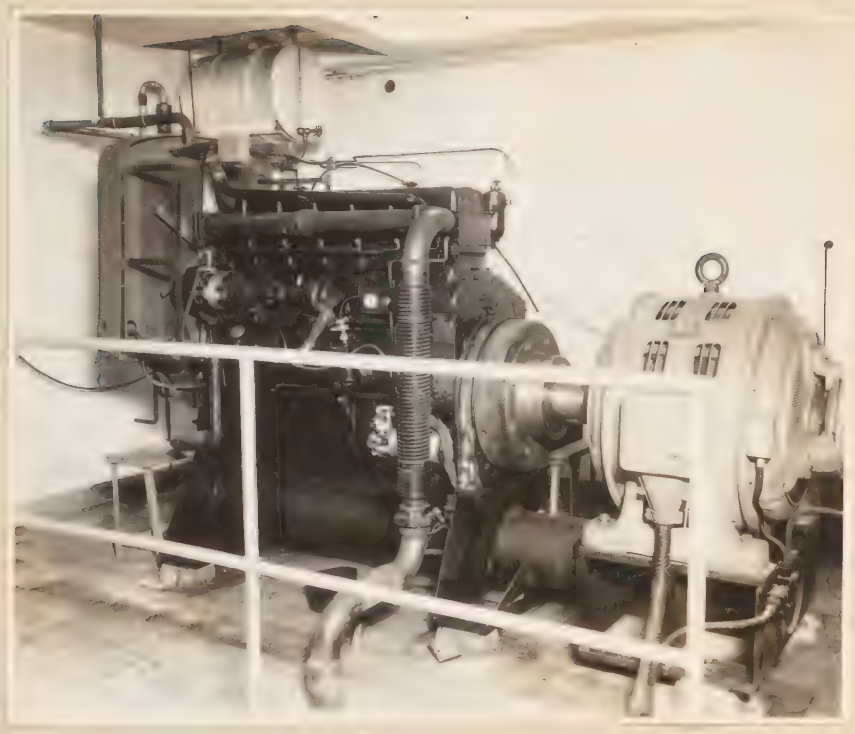


Illustration 7

Diesel powered electric generator.

Ill. 8

Illustration 8

Patients room. Nurses complained of lack of storage space. Note gas tight seal on wall near ceiling. Outer end of this opening can be seen in illustration 3

Ill. 9

Illustration 9

Utility room. Note glazed tile on wall and terrazzo type of floor tile. Nurse's pin indicates she belongs to "Deutsches Rotes Kreuz".

Illustration 10

Doctors scrub room. Surgery can be observed through the window.

Ill. 10

Illustration 11

Operating Room.

Ill. 12

Illustration 12

View of ventilating duct on ceiling. Outlets along the side are not visible in the shadow. Gas tight outlets to the passageway are seen on the wall.

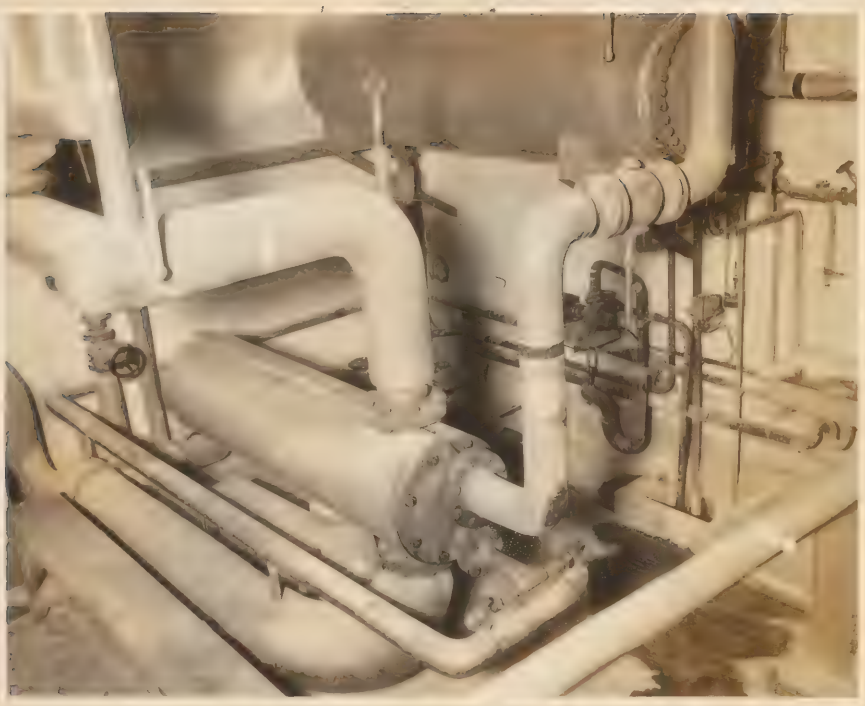


Illustration 13

In the foreground is the heating apparatus where hot water from the old hospital heats air to be pumped through the radiators of the bunker. Hot water radiators were considered to be a hazard. The heating system was separate from the ventilating system. In the lower background is the sump pump.

# THE SUBTERRANEAN OPERATION BUNKER IN MANNHEIM ON THE NECKAR

## A. GENERAL SURVEY

### The Project.

Mannheim has 250,000 inhabitants and is the center of many principal thoroughfares and junction of a large net of railroad lines, therefore, and because of its vicinity to the French border it was considered as particularly endagered by air attacks from the very beginning of the war. The City faced the problem to provide bombproof operation facilities for the main hospital which has about 1,500 beds. The construction of the operation bunker started in 1940 and the original plan answered only minimum requirements. The competent authorities had not yet gained any experience on what an air raid was like. This situation explains the fact that the bunker can only accomodate 30 patients. With a view to facilitate the transport of the patients from the operation rooms of the hospital to those of the bunker a place in the immediate vicinity of the surgical department was chosen. A subterranean construction was necessary with regard to the surrounding buildings. The bunker has only one story and is connected with the surgical department by a ramp with an inclination of 10%. The bunker connects with the outside by a staircase. Both entrances are protected by air locks. The corridors provided additional space for patients in beds or on benches.

### Time of Construction

The construction of the bunker started in 1940. The concrete construction was finished in April 1941. From then on the bunker was used as an air-raid shelter. Due to supply difficulties the medical equipment was built in only in October 1941 and from November 1941 on the bunker was in full operation.

### General Description of the Construction

The bunker is located between the buildings of the hospital which lines the Neckar river. The structure is below ground and the top is covered with 50 centimeters of soil to make it level with the ground. The structure has the shape of a T. The top of the T contains the operation and ante rooms as well as, the engine rooms. The leg contains several patients rooms and the necessary sanitary installations.

## Capacity of the bunker

The bunker was planned for 30 beds to accomodate the patients the first few days after the operation. About 60 to 80 patients could accomodated in the corridors. The ventilation system was laid out for 150 to 200 persons.

## Damage by bombs.

The bunker itself was not hit. Light bombs fell, however, at a distance of about 100 meters and caused a perceptible shaking of the bunker. The detonation was not distinctly heard. No damage occurred.

# B. TECHNICAL DETAILS

## Workforce.

The bunker was built in three shifts, that is to say also at night time. Each shift amounted to about 80 men. During air raids the work was interrupted at the most critical moments. The work had furthermore to be suspended for a few weeks during the winter 1940/41 due to cold. The work was continued even when there was a moderate frost when a quick setting cement was used. The exact details concerning the resistance of the concrete and the mixing ratios could not be obtained since all documents have been destroyed in the air raids on Mannheim. According to the information of the foreman, cubic resistances up to 500 kilograms per square centimeter were obtained. Sand of the Rhine River, gravel and porphyre split were used as admixing ingredients. The granulations were in conformity with the German DIN Standards Nr. 4226. According to the plan the quantity of cement per one cubic meter of concrete was calculated at 400 kilograms, this would correspond to a mixing ration of 1:4.

## Steel

The reinforcing steel (German standard St 3712 = normal construction steel) was introduced in the static calculation with the admissible maximum force of 1200kg/cm$^2$. Small diameters up to 18 millimeters allowed a favorable distribution of the steel over the total space of the structure.

## Foundation

The bunker lies on a filled in site on the embankment of the Neckar River. The average ground water level is below the base of the bunker. Since enough space was

available the bunker was built in an open sloped trench. Provision was made that the water could be pumped out in case of an inundation.The insulation against subsoil water consisted of several layers. A 30 centimeters thick layer of reinforced concrete takes up the pressure of the water. On top of this is a layer of cement plaster to take up the insulation properly speaking. The insulation was achieved by a layer of sheet aluminium, on both sides of which a thick layer of bitumen was fused. The base insulation was connected with the insulation of the lateral walls by soldering. A protective layer of concrete follows on this insulation which takes up the reinforced concrete floor of the bunker.

## C. CONSTRUCTION COMPONENTS

### Base of the Bunker

The construction of the floor of the bunker was described above. It was covered with xylolite and partly with terrazo.

### Bombproof Ceiling of the Bunker

The ceiling is 1.40 meter thick and is reinforced by a cubic system of steel placed at a slant. The reinforcement consists of a system of single rods which are connected with each other. Steelwire nets were not used for reinforcement purposes, next to the inner side of the ceiling, however, a wirenet was imbedded to prevent destroyed concrete from falling down. The thin ceiling can be explained by the early construction of this bunker. On top of this layer follows an ordinary concrete slab which is then covered by the described aluminium insulation which is again protected by a thin layer of cement plaster. On top, the bunker is made level with the ground by a thin layer of soil. The ceiling was made as one slab and fabricated in 17 hours.

### Outside Walls.

The outside walls are 1.80 meter thick and insulated with aluminium sheet metal. The insulation is protected by a layer of cement mortar. The walls were then lined outside by a brick wall (25 centimeters thick). The inner sides were likewise lined by a 12 centimeters thick brick wall which has excellent insulation properties. The reinforcement of the outside walls resembles that of the ceiling.

## Partition Walls

The partition walls were made of bricks and were relatively thick. (25 and 38 centimeters). This was done to obtain a good sound insulation.

## Passages

The passages are built bombproof. The ramp inside the bunker consists of a self contained steel concrete slab to the lower side of which the water, sewage and ventilation tubes are suspended. The batteries are also stowed away under this ramp next to the engine room.

## Outside Staircase

The outside staircase has a convenient rise and leads to the level of the floor of the bunker and from there in a zigzag to the air lock. The angles were convenient in consideration of an unhampered transportation of the patients.

## Plumbing and Wiring

The tubes are laid on the wall or suspended to the ceiling to afford good access in case of necessary repairs. This disposition presents, however, a hazard by the possible deposits of dust.

# D. DESCRIPTION OF THE ROOMS.

## The sterilization Room

The sterilization room connects with the ramp, the size is 3 by 7.60 meters. The floor is covered with terrazo, the walls are plastered and painted with oil paint. An autoclave with 50 liters capacity and two sterilizers for steam and electricity are available. Wash basins and sinks are installed. It is worthwhile mentioning that each faucet has an individual filter which is automatically operating, if the water is drawn from the shaft. The wall next to the operation room is lined with closets which may be used on both sides. A wide sliding door opens on the operation room . Two ventilation devices are suspended to the center of the ceiling.

## The Ante-Room

The ante-room next to the operation room serves as an anaesthesia room and measures 5.20 by 5 meters. The room

has the customary washbasins and built in closets. The ventilation is suspended to the ceiling in the middle of the room.

## Operation Room

The operation room measures 5,20 by 8,15 meters and has two operation tables. The room connects with the sterilization and anaesthesia room. The room is held at a temperature of 38° Celsius by hot air which streams in the room from 8 nozzles. For safety's sake the room was provided with a double ceiling as a protection against falling concrete in case the bunker should be seriously hit. This double ceiling is fixed between two double T beams and consists of plasterslabs 8 centimeters thick. Thus a hollow space of about 10 centimeters is created between the two ceilings. The ceiling is covered with plaster and painted with oil paint. The exhaust tubes have their intake openings next to the floor and do not communicate with the general ventilation system to avoid that ether filled air gets into it. In the center of the floor is a floor drain with a special trap. The floor is covered with terrazzo.

## Engine Room.

The engine room contains all the elements necessary to make the bunker selfsustaining. The size of the engine room is 5,13 by 7,62 meters. Ceiling and sidewalls are made soundproof by a special sound insulation. A Diesel engine with a capacity of 150 kilo Volt per hour at 1000 revolutions is said to be of the type of the Diesel engines used at that time for the submarines. The engine is placed on a special sound absorbing base. The bunker may be heated either by hot air or by electric heaters. In 1945 the bunker was connected with the central heating plant of the hospital.

## Patient-Rooms

The patient rooms were intended to accomodate 3 patients and measures 3,15 by 5 meters. During the war, however, the beds were arranged in tiers of two to obtain room for more patients. The patients rooms are separated from the corridor by reinforced concrete walls 60 centimeters thick. The height of the rooms is 2,70 meters.

## Toilets.

Lavaratories are located between the toilets and the corridors to prevent odors to excape into the floors. Under the floor of the toilet is the waste water collector taking up the entire waste water of the bunker. A floater actuates the pump as soon as the waste water rises to a certain level and the contents are pumped into the sewage pipe. The outlet of the City sewage pipe is provided with the necessary traps to prevent a back flow. A special par-

tition in the collector makes the heavy sewage sink and this lower part of the collector has to be emptied from time to time.

### Pantries.

A pantry is provided which contains an electric stove and refrigerator as well as a couple of closets and storing space. The walls are painted with oil paints. The height of the room is 2.70 meters.

## F. SUPPLY MAINS.

### Water supply

The water is generally taken from the City Mains. In an emergency case it is possible to operate a shaft pump. The water so obtained requires special treatment, therefore we find filters in operation as soon as the water is drawn from the shaft.

### Supply of Electricity.

Electricity is supplied by the City mains. If the mains give out, a Diesel generator is used. The time until the Diesel unit attains the full capacity is bridged over by batteries. ( See under "engine room").

### Supply of Gas.

Gas is not available in the bunker in consideration of explosion hazards and the additional consumption of oxygen.

### Ventilation

Fresh air which is drawn in by suction pumps, is then cleaned, washed, filtered and heated to the convenient room temperature and forced into the rooms.

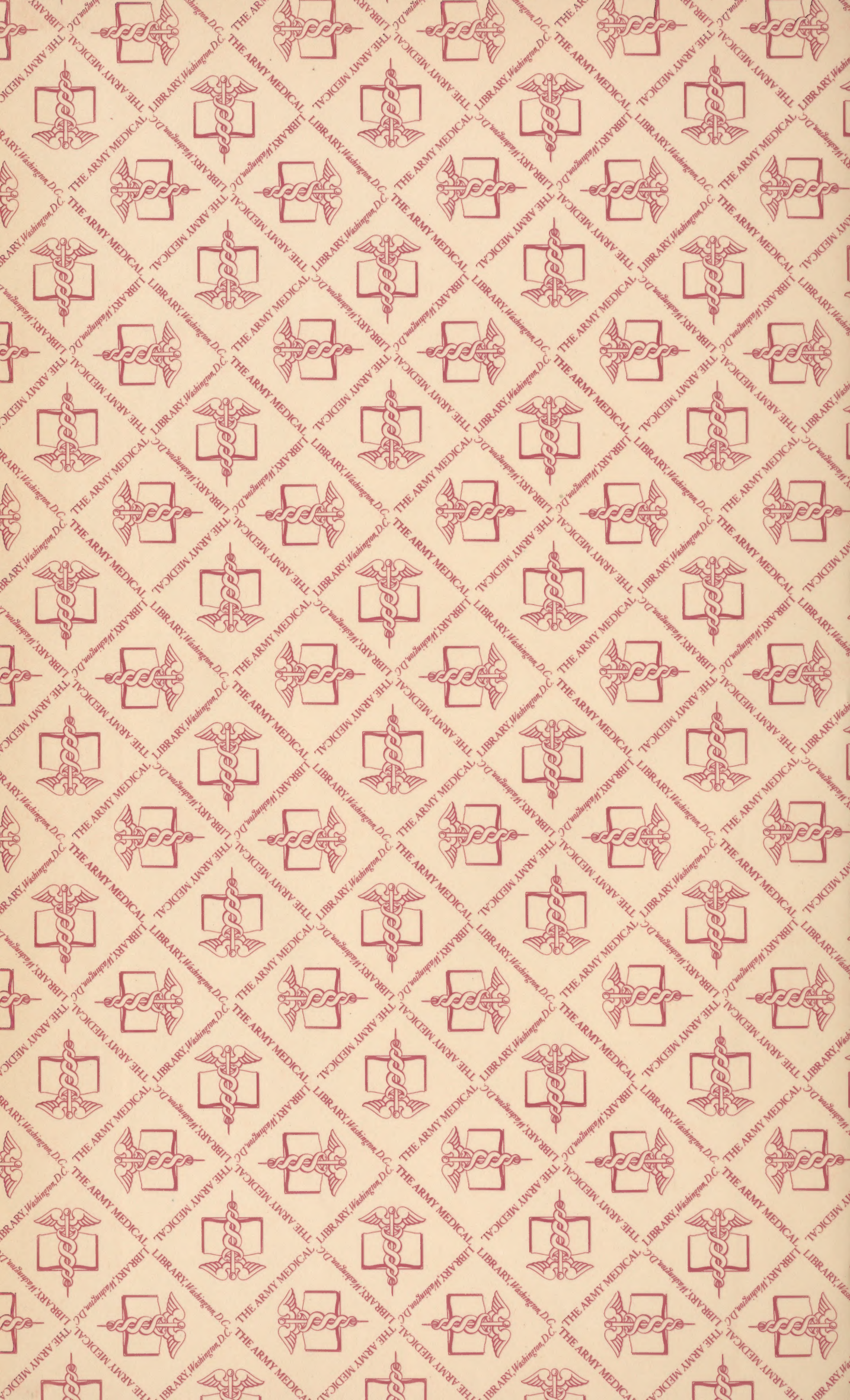
### Heating.

The bunker connects at the present time with the heating installation of the hospital.

## G. OPINIONS ON THE BUNKER

### Opinion of the Doctors.

The bunker has proved far too small for the great number of patients during the air raids. Two more bunkers of similar size had been planned but never completed because of the events. An X-ray room would have been necessary under all circumstances. The sterilization of the instruments was said to be partly jeopardized by the constant whirling of dust. The freely suspended tubes under the ceilings were considered particularly hazardous in this respect. Furthermore tiles would have been more suitable than a simple oil paint.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